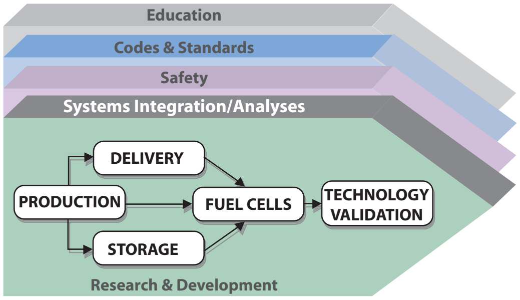
4.0 Systems Analysis



Systems Analysis supports decision-making by providing greater understanding of the contribution of individual components to the hydrogen energy system as a whole, and the interaction of the components and their effects on the system. Analysis will be used to continually evaluate the alternatives for satisfying the functions and requirements of the future hydrogen system/economy and the Program's progress against the targets outlined in this RD&D Plan. Analysis is conducted to assess cross-cutting and overall hydrogen system issues, and to support the development of the production, delivery, storage, fuel cell and safety technologies. The Systems Analysis activities are led by the DOE Technology Analyst and are supported by the Systems Integration function, which provides analytical resources, models and tools, and independent analysis capabilities as required.

4.1 Technical Goal and Objectives

Goal

Support decision-making by evaluating existing and emerging technologies, utilizing a fact-based analytical framework to guide the selection and evaluation of RD&D projects, and providing a sound basis for estimating the potential value of research and development efforts.

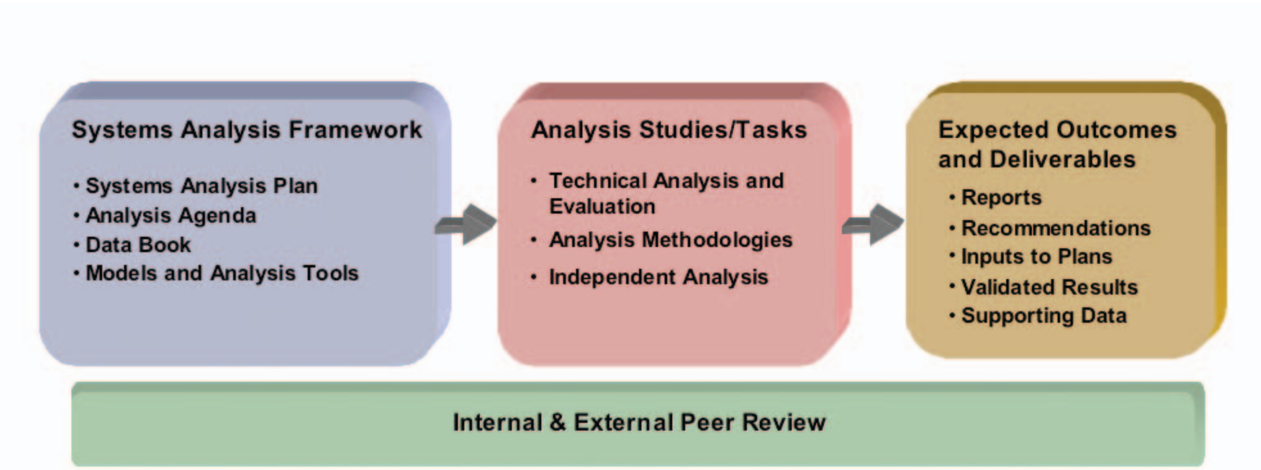
Objectives

- Through analysis, continuously support the integration of the Program within a balanced, overall DOE national energy R&D effort—addressing the role of hydrogen in context of the overall energy infrastructure.
- By 2007, identify and evaluate transition scenarios consistent with developing infrastructure and hydrogen resources, including an assessment of timing and sequencing issues.
- Continuously provide and/or coordinate appropriate and timely analysis of environmental and technoeconomic issues to support decision-making tied to Program schedules, targets and milestones.
- By 2008, develop and utilize a macro-system model of the hydrogen fuel infrastructure to support transportation systems. By 2010, enhance the model to include the stationary electrical generation and infrastructure for a full hydrogen economy.
- Continuously support a spectrum of analyses, including financial and environmental assessments, across and within Program elements—from individual unit/subsystem elements to a fully integrated system and infrastructure.

4.2 Technical Approach

The overall approach to implementing a robust Systems Analysis capability is based on the need to support Program decision-making processes and milestones, provide independent analysis when required to validate decisions and/or ensure objective inputs, and respond to external review recommendations. As depicted in Figure 4.2.1, the approach provides the direction, planning, and resources/tools through the systems analysis framework, the ongoing and planned studies and tasks, and the value-added products. To ensure that the effort is properly focused, frequent, objective and effective, internal and external peer reviews are conducted.

Figure 4.2.1 Systems Analysis Approach Overview



4.2.1 Systems Analysis Framework

Systems Analysis Plan. A detailed Systems Analysis Plan (SAP) is being developed to lay out the overall approach, tasks and processes for the systems analysis efforts of the Program. The SAP will contain a catalog of resources, the systems analysis processes, the analysis results and supporting documentation.

Analysis Portfolio. A portfolio of technical analysis and evaluation activities will be established. The portfolio will be prioritized based on need to better understand system requirements, support Go/No-Go decisions, and evaluate progress towards the milestones and technology development goals of the program. The analysis portfolio will be updated periodically to ensure that the analytical activities provide direction, focus and support to the Program's research and development activities.

Data Book. A technical data management system will be developed to provide a consistent database, a list of assumptions, information standards and tools for capturing needed information. This repository will serve as the standard input to systems analysis, and will be used to establish the base case hydrogen system and conduct the subsequent trade-off analyses. The technical data management system will ensure consistency in analyses conducted by the Program. The database will be updated annually and made available to the community through the Web.

Models and Analysis Tools. Systems analysis tools support capturing the results of individual efforts, reviewing progress against stated objectives, and conducting ongoing evaluations that advance the Program objectives. Modeling tools will provide the basis for analyzing alternatives at the system-, technology-, or component-level in terms of their cost, performance, benefit and risk impacts on the macro system. Numerous models exist or are under development by national laboratories, industry and academia within the hydrogen system functional areas (production, delivery, storage, etc.). Systems Analysis will add a macro-system model to the current model portfolio to conduct overarching analysis and trade-off comparisons. A modeling architecture will be defined to provide consistency among the models employed for analysis, and to sustain the integrity and continuity of the outputs and results.

4.2.2 Analysis Studies/Tasks

Technical Analysis and Evaluation. The potential technology pathways for wide-scale hydrogen implementation will be modeled and analyzed from the standpoints of application requirements (targets), costs, risks, and environmental and societal impacts on a macro-system basis. Key cost and technology barriers/gaps will be identified. These results will help to further define and update the key RD&D needs and plans within each of the Program elements. Systems analysis will be used to update energy, environmental and financial impact/risk projections. To achieve these results, the analysis activities will follow a modeling methodology covering a wide spectrum of analysis needs. The types of analyses required to plan, execute and evaluate the RD&D activities are described in Table 4.2.1.

Table 4.2.1. Analysis Methodologies

Analysis Type	Description
Resource Analysis	Determines the quantity and location of resources needed to produce hydrogen. Additionally, resource analysis quantifies the cost of the resources as a function of the amount that can be available for hydrogen production. Geographic Information Systems (GIS) modeling is often used to portray and analyze resource data. GIS can also represent the spatial relationship between resources, production facilities, transportation infrastructures and demand centers.
Technology Feasibility and Cost Analysis	Determine the potential economic viability of a process or technology, and identify technologies that have the greatest likelihood of economic success. The technical feasibility assesses the basic viability of the process. The results from technology feasibility analysis provide input to balanced portfolio development and technology validation plans.
Environmental Analysis	Quantifies the environmental impacts of technologies. Specifically, life cycle assessment is used to identify and evaluate the emissions, resource consumption and energy use for all steps in the process of interest, including raw material extraction, transportation, processing and final disposal of all products and by-products. Also known as cradle-to-grave or well-to-wheels analysis, this methodology is used to better understand the full impacts of existing and developing technologies, such that efforts can be focused on mitigating negative effects.
Delivery Analysis	Identifies the most economic options for delivering hydrogen and provides a foundation for additional research on alternative storage and transportation options. Additionally, delivery analysis provides crucial information to technology feasibility analysis in determining the optimal production capacities and locations. Delivery analyses will be conducted to determine the most promising technologies, as inputs to other technical elements of the Program.
Infrastructure Development	Quantifies the total costs of scenarios for developing the hydrogen infrastructure, including production, delivery and utilization. Infrastructure development analysis can identify economical routes and financial risks for providing the lowest delivered cost of hydrogen from combinations of central and distributed production facilities. Evaluations of the costs, impacts on existing infrastructures and timelines of various scenarios for the hydrogen infrastructure will be conducted.
Macro-System Analysis	Analyzes the interrelationships within the system utilizing the tools and results from the range of analysis methodologies. Identifies critical interface issues and system optimization opportunities. Through scenario analysis, identifies the most viable routes for achieving the hydrogen future, and the costs and benefits associated with these pathways.

Independent Analysis. Independent analysis will be an integral part of Systems Analysis to ensure credibility, validate methodologies and data, and provide perspective. Independent analysis is accomplished by utilizing experts and analysts who have not been directly involved in the management, research and development, analysis, evaluation, or recommendation efforts related to the activity in question. Such outside experts often possess unique insight into particular issues that can benefit ongoing analysis activities. Independent analysts may be brought in to provide input to key program milestones, such as technology down-select decisions, and to provide recommendations on changes to major technical targets.

4.3 Analysis-Specific Roles and Responsibilities

Hydrogen Systems Analysis is the responsibility of the DOE Technology Analyst, supported by the Program's Systems Integrator. The overall team involves the Program element leads, FreedomCAR and Fuel Partnership Technical Teams, and the people and organizations that perform the analysis activities. A summary of the individual analysis responsibilities of these positions and groups is provided below:

Technology Analyst

- Accountable for analysis activities
- Provides inputs and sets priorities for the Analysis Portfolio
- Ensures communication of consistent data and information
- Coordinates analysis done in support of the Program

Systems Integrator

- Establishes priorities for the Analysis Portfolio (including technical and time pathways)
- Develops and maintains consistent data and information, and standard analysis assumptions and guidelines
- Provides independent analysis (e.g. for Go/No-Go recommendations)
- Ensures tools/models are developed, maintained, available and validated

Program Element Leads

- Provides inputs to the Analysis Portfolio
- Provides recommendations on cross-cutting analysis
- Manages analysis tasks internal to the Program element

DOE/EERE Office of Planning, Budget and Analysis (PBA)

- Provides market and benefits analysis related to hydrogen and energy infrastructure
- Reviews analysis priorities
- Coordinates activities and exchanges results with the Technology Analyst and Systems Integrator

FreedomCAR and Fuel Partnership Technical Teams

- Provides recommendations to DOE on analysis needs and issues
- Reviews studies and analysis results
- Develops technical targets based on system and customer requirements

4.4 Programmatic Status

Current Activities

Major Systems Analysis activities are listed in Table 4.4.1.

Table 4.4.1. Current Systems Analysis Activities

Topic	Approach	Organization
Resource Analysis	• Quantify location, amount and cost of resources • Develop GIS resource maps for use in infrastructure development studies	**National Renewable Energy Laboratory (NREL):** GIS studies of renewable resources for hydrogen
Technology Feasibility and Cost Analysis	• Determine potential economic viability of hydrogen technologies • Guide Program research activities by identifying cost reduction opportunities and critical development paths	**NREL, Pacific Northwest National Laboratory (PNNL), Argonne National Laboratory (ANL), Directed Technologies, TIAX, UC-Davis, Technology Insights and Parsons Engineering:** Standards and tools for consistent analysis of hydrogen technologies (H2A; details of H2A Analysis model are presented in Appendix E) **NREL:** Technoeconomic analysis of current research projects and case studies of competing and complementary production technologies
Environmental Analysis	• Conduct well-to-wheel analysis to compare existing and developing transportation technologies • Assess climate impact of the hydrogen economy • Determine environmental impacts of hydrogen technologies	**PNNL:** Incorporating hydrogen-specific technologies into long-term climate model **ANL:** Fuel cell vehicle benefits analysis using GREET and VISION models **Tellus:** Greenhouse gas impacts of transition scenarios **NREL:** Environmental analysis of hydrogen production technologies
Delivery Analysis	• Analyze systems and infrastructures for delivery of gaseous and liquid hydrogen and novel solid/liquid hydrogen carriers	**PNNL, NREL and ANL:** Components modeling; compression technology and issues; ethanol delivery infrastructure characterization; and hydrogen delivery scenario modeling **Nexant, Inc., Air Liquide, ChevronTexaco, NREL, Gas Technologies Institute, Pinnacle West, and TIAX:** Cost/ environmental analyses for delivery scenarios as a function of time and demand
Infrastructure Development	• Evaluate cost impacts and timelines of various scenarios for developing hydrogen infrastructure • Identify economical routes and financial risks of hydrogen production and delivery technologies	**Oak Ridge National Laboratory (ORNL) and ANL:** HyTrans hydrogen infrastructure model to study fuel cell vehicle market penetration **NREL:** Geographic-specific hydrogen infrastructure model to study hydrogen production and its interface to the electric grid **UC-Davis and NREL:** Assessment of geographic locations for hydrogen fueling stations and infrastructure **TIAX:** Impacts of fuels choice on transportation infrastructure **RCF, ANL, Air Products, BP, Ford, WRI and University of Michigan:** Analysis of the hydrogen production and delivery infrastructure as a complex adaptive system **Direct Technologies, Inc., Sentech, H2Gen, ChevronTexaco and Teledyne:** Hydrogen production infrastructure options analysis **Energy and Environmental Analysis, BNL, Power and Energy Analytic Resources:** Impact of hydrogen production on U.S. energy markets
Market/Benefits Analysis	• Enable broad understanding of the hydrogen economy in the context of energy infrastructure • Assess the potential benefits and impacts of hydrogen and competing technologies	**EERE/PBA:** Interrelationship of the hydrogen economy to the overall energy infrastructure; market and benefits analysis of hydrogen and fuel cell vehicles

4.5 Technical Challenges

The following discussion details the various technical and programmatic barriers that must be overcome to attain the Systems Analysis goal and objectives.

Barriers

A. Lack of Prioritized List of Analyses for Appropriate and Timely Recommendations. Systems analysis and its resulting observations and recommendations are only of value if they address the key decisions faced by the Program and are tied to the schedules and milestones of those decision processes. Resource constraints, fluid budgets and evolving technologies impact the setting of analysis priorities.

B. Lack of Consistent Data, Assumptions and Guidelines. Analysis results are strongly influenced by the data sets employed, as well as the assumptions and guidelines established to frame the analytical tasks. These elements have been largely uncontrolled in the past, with individual analysts and organizations making their own value decisions. Although this does not necessarily make the results wrong, it does make it more difficult to put the results and ensuing recommendations in context with other analyses and the overall objectives of the Program. Establishing a Program-endorsed consistent set of data, assumptions and guidelines is challenging due to the large number of stakeholders involved and the breadth of technologies and system requirements.

C. Lack of a Macro-System Model. Although numerous models exist to analyze components and subsystems of an eventual hydrogen economy, a modeling architecture does not exist that addresses the overarching hydrogen fuel infrastructure as a "system." Such a macro-system model is critical to assessing the transition from the existing energy infrastructure to one including hydrogen. Individual models spanning a wide range of modeling platforms (operating systems, software, inputs, outputs, boundary conditions, etc.) must be integrated into a common macro-system model.

D. Stove-Piped/Siloed Analytical Capabilities. Analytical capabilities and resources have been largely segmented, both functionally by Program element (production, storage, fuel cells, etc.) and organizationally (laboratories, specialized teams, industry/academia, etc.). Successful systems analysis requires the integration of analysis resources across all facets of the infrastructure.

E. Lack of Understanding of the Transition of a Hydrocarbon-Based Economy to a Hydrogen-Based Economy. The long-term hydrogen fuel infrastructure is little understood and numerous economic, social, political and technical influences will be involved in the transition to the hydrogen economy. In addition, the overall energy infrastructure and economy into which hydrogen must fit is an ever-changing domain.

4.6 Target Setting Process

The objective of target setting is to set a realistic standard for focusing and assessing the research and development efforts. The technical targets are an essential part of the Program and key to achieving the goals and objectives of lowering cost, improving energy efficiency and ensuring reliable performance. The targets are driven by the system level and consumer requirements necessary for them to be competitive for use in light-duty vehicle transportation and stationary power markets. For example, for light-duty vehicle transportation, hydrogen fuel cell vehicles will need to compete with internal combustion engine and/or hybrid electric vehicles on a cost and performance basis. The hydrogen fuel cost target is based on the need to compete with gasoline on a cents-per-mile basis and is independent of the production pathway. The hydrogen storage and fuel cell targets reflect consumer expectations for vehicles with a range greater than 300 miles and system costs that are on parity with the convention.

While system requirement targets are set based on a top-down approach, a bottom-up approach is also used to determine if targets are realistic for specific technologies (e.g. thermodynamically feasible), to track progress towards achieving the targets, and to set priorities for cost reduction and performance improvements. As technology progresses and more is learned about the system-level requirements, the targets may be further refined.

4.7 Technical Task Descriptions

The technical task descriptions are presented in Table 4.7.1. The Systems Analysis function is in the initial stages of operation. Therefore, the tasks are currently process oriented and designed to establish the key elements required for on-going analysis.

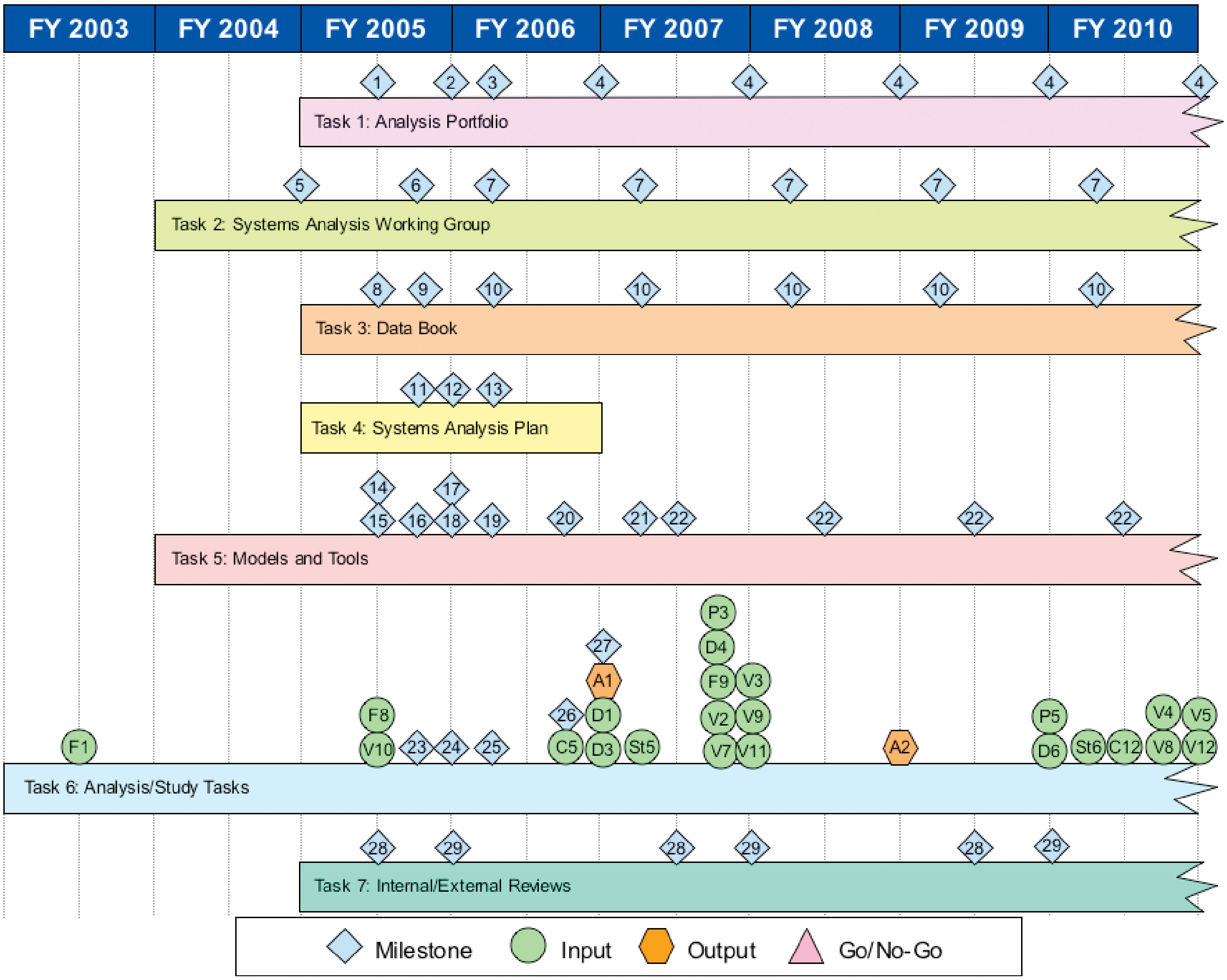
Table 4.7.1. Current Systems Analysis Activities

Task	Description	Barriers
1	**Analysis Portfolio** • Develop and maintain the Analysis Portfolio, a prioritized listing and description of the analysis tasks needed to support programmatic and technical milestones • Update the portfolio as required (at least annually to support budget preparation timelines) • Integrate the portfolio in Systems Analysis planning	A, B, C, D, E
2	**Systems Analysis Working Group** • Sponsor, establish and lead a hydrogen analysis community group to mature and coordinate systems analysis for the Program • Coordinate analysis activities with the DOE Offices of Fossil Energy and Nuclear Energy, Science and Technology • Work with the EERE Office of Planning, Budget and Analysis to integrate and coordinate market/ benefits analysis with the Program needs	A, B, D, E
3	**Data Book** · Develop standard and consistent analysis data, assumptions, guidelines, and scenarios · Maintain the Data Book through a configuration managed change process · Provide access to the Data Book via a web-based interface	B
4	**Systems Analysis Plan** · Catalog current resources, systems analysis processes and analysis results, including supporting documentation · Develop an overall Systems Analysis Plan to guide the systems analysis activities of the Program, integrating input from the analysis community (Systems Analysis Working Group, Technical Teams, H2A, etc.)	A, B, C, E
5	**Models and Tools** · Complete the development of requirements for the Macro-System Model (MSM) · Develop the overall MSM architecture and choose the infrastructure hardware/software implementation · Determine standard input/output schemes for utilization within the MSM · Capture MSM requirements, description, and usage in the MSM Description Document · Develop plans for supporting models, including optimization, transition, delivery, environmental, fuel cell vehicle and combined energy	C, E
6	**Analysis/Study Tasks** · Conduct systems analysis/study tasks in key areas to support Program decisions and milestones	A, D, E
7	**Internal/External Review** · Conduct an internal review of systems analysis activities to ensure that plans and execution are in line with Program needs · Conduct an external peer review of the Systems Analysis function to measure progress	A

4.8 Milestones

Figure 4.8.1 shows the interrelationship of milestones, tasks, supporting inputs from other Program elements, and technology/analytical outputs from the Systems Analysis function from FY 2005 through FY 2010. This information is also summarized in Table B.9 in Appendix B.

Figure 4.8.1. Systems Analysis R&D Milestone Chart



For chart details see next page.

Milestones

1 Complete survey for Analysis Portfolio from all sources.
2 Complete 1st draft of prioritized Analysis Portfolio.
3 Publish Analysis Portfolio.
4 Annual update of Analysis Portfolio.
5 Establish Systems Analysis Work Group and Complete 1st Systems Analysis Workshop.
6 Complete 2nd Systems Analysis Workshop with hydrogen analysis community.
7 Annual Systems Analysis Workshop to review updated Analysis Portfolio and Data Book.
8 Survey hydrogen community for assumptions, data sets, targets and constraints for input to the database.
9 Complete "Review Version" of Data Book and issue for comment.
10 Complete 1st edition of Data Book and subsequent annual updates.
11 Complete "Review Version" of the Systems Analysis Plan.
12 Peer review the Systems Analysis Plan.
13 Complete 1st edition of the Systems Analysis Plan.
14 Complete model review for model architecture.
15 Complete transition model review.
16 Complete input/output guidelines for the Macro-System Model.
17 Select transition model for analysis and incorporate into Macro-system Model.
18 Develop initial model architecture.
19 Capture Macro-System Model requirements, description, and usage in a description document.
20 Peer review the Macro-System Model with the hydrogen modeling community.
21 Complete 1st version of the Macro-System Model.
22 Complete the integration of the Macro-System Model into the Systems Analysis and accomplish annual major model upgrades (2010 includes electricity infrastructure).
23 Complete evaluation of the factors (geographic, resource availability, existing infrastructure) that most impact transition analysis.
24 Complete baseline economic, energy efficiency and environmental targets for fossil, nuclear and renewable hydrogen production and delivery technologies.
25 Begin a coordinated study of transition analysis with H2A and Delivery models.
26 Complete study for transitioning scenarios for a hydrogen economy.
27 Complete assessment of current technologies for production and delivery pathways to meet the established targets.
28 Internal review of Systems Analysis function biennially.
29 External Peer review of Systems Analysis function biennially.

Outputs

A1 Output to Production, Delivery and Systems Integration: Complete techoeconomic analysis on production and delivery technologies currently being researched to meet overall Program hydrogen fuel objective.
A2 Output to Program: Initial recommended hydrogen quality at each point in the system.

Inputs

F1 Input from Fuel Cells: Critical analysis of well-to-wheels studies of fuel cell system performance, efficiency, greenhouse gas emissions and cost.
F8 Input from Fuel Cells: Preliminary hydrogen purity/impurity requirements.
V10 Input from Technology Validation: Hydrogen refueling station analysis - proposed interstate refueling station locations.
C5 Input from Codes and Standards: Hydrogen fuel quality standard as ISO Technical Specification.
D1 Input from Delivery: Assessment of cost and performance requirements for off-board storage systems.
D3 Input from Delivery: Hydrogen delivery infrastructure analysis results.
St5 Input from Storage: Baseline hydrogen on-board storage system analysis results (and initial down-select) including hydrogen quality needs and interface issues.
P3 Input from Production: Impact of hydrogen purity on cost and performance.
D4 Input from Delivery: Assessment of impact of hydrogen purity requirements on cost and performance of hydrogen delivery.
F9 Input from Fuel Cells: Updated hydrogen purity/impurity requirements.
V2 Input from Technology Validation: Final report for first generation vehicles and interim progress report for second generation vehicles, on performance, safety and O&M.
V7 Input from Technology Validation: Final report on infrastructure, including impact of hydrogen purity on cost and performance.
V3 Input from Technology Validation: Technology status report and re-focused R&D recommendations.
V9 Input from Technology Validation: Final report on safety and O&M of three refueling stations.
V11 Input from Technology Validation: Composite results of analyses & modeling from vehicle and infrastructure data collected under the learning demonstration project.
P5 Input from Production: Impact of hydrogen purity on cost and performance.
D6 Input from Delivery: Update of hydrogen purity/impurity requirements.
St6 Input from Storage: Final on-board hydrogen storage system analysis results of cost and performance (including pressure, temperature, etc.) and down-select to a primary on-board storage system candidate.
C12 Input from Codes & Standards: Final hydrogen fuel quality standard as ISO Standard.
V4 Input from Technology Validation: Final report for second generation vehicles on performance, safety and O&M.
V8 Input from Technology Validation: Final report on infrastructure, including impact of hydrogen purity on cost and performance.
V5 Input from Technology Validation: Technology status report and re-focused R&D recommendations.
V12 Input from Technology Validation: Composite results of analyses & modeling from vehicle and infrastructure data collected under the Learning Demonstration Project.